Making Smart Mobility Smarter, Faster

Aymeric Rousseau
Argonne National Laboratory

Funded by US DOE VTO
David Anderson

System Considerations Critical for Automated, Connected, Efficient and Shared Mobility

As Mobility and Technology Evolves, so Must Analytical Tools for New Knowledge

Single Vehicle | **Corridor / Small Network** | **Entire Urban Area**

AUTONOMIE

- Vehicle energy consumption, performance and cost
- Only commercial tool with vehicle level control
- Licensed to >250 companies

RoadRunner

- Only system simulation of multi-vehicles and their environment focused on advanced control enabled by V2V, V2I…
- Uses Autonomie powertrain models

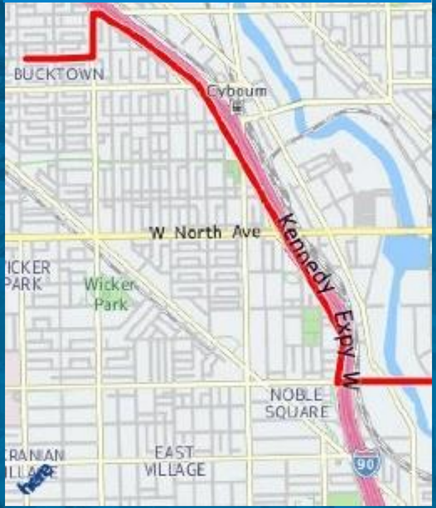
POLARIS

- Agent-based mesoscopic traffic flow simulation
- Focus on traveler behavior, transport modes, technologies

Predict Vehicle Trip Profile

- Supports Eco-Routing
- Required for Predictive Control

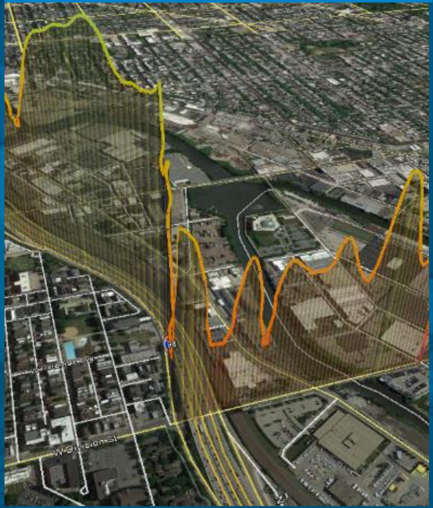
Trip definition Origin, destination, waypoints



HTTP REST query

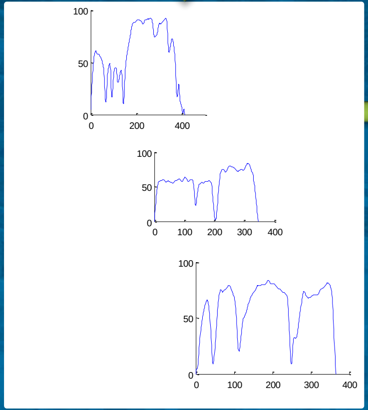
Route data and data tiles

Naturalistic Speed Trace with Grade

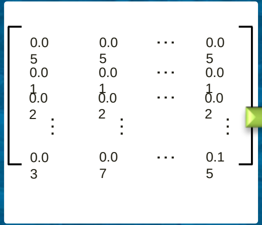


Real-World Stochastic Aspect Introduced by Constrained Markov Chains (SVTrip)

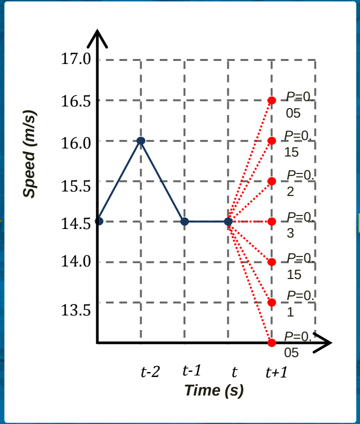
Chicago Travel Survey
(10k vehicle trips, 6M data points)



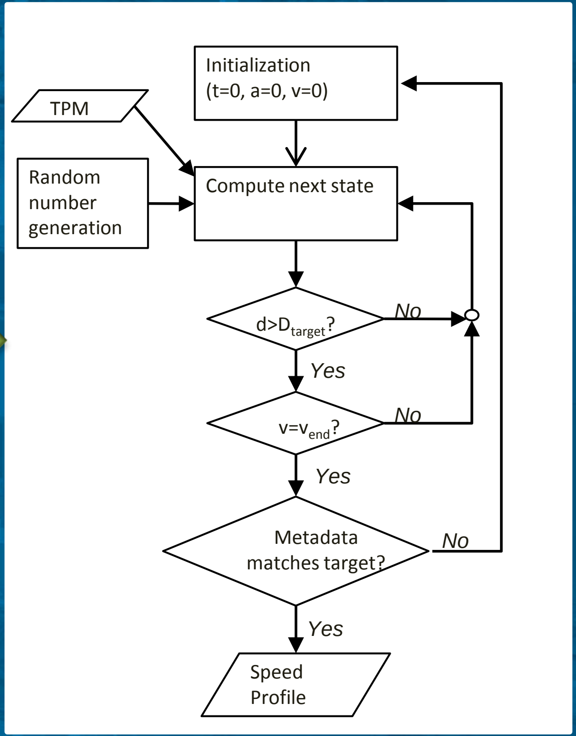
Valid Real-World Micro-Trips



Transition Probability Matrix



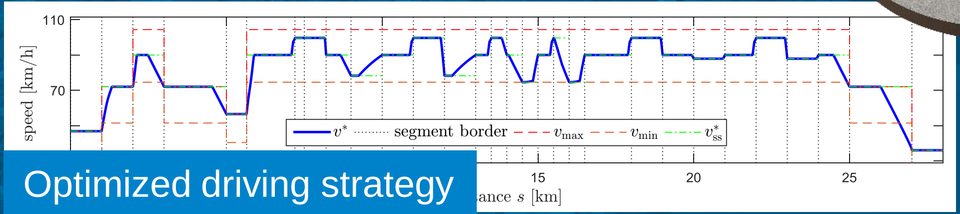
Markov Chains



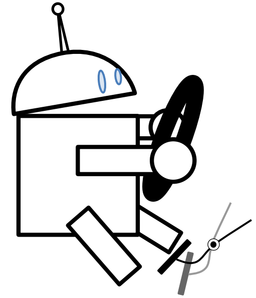
Constrained Markov Chain

Model Predictive Control Used to Minimize Energy Consumption

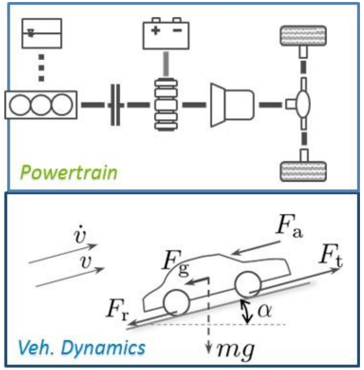
Road Horizon
(grade, speed limit)



Optimized driving strategy



Automated Driving

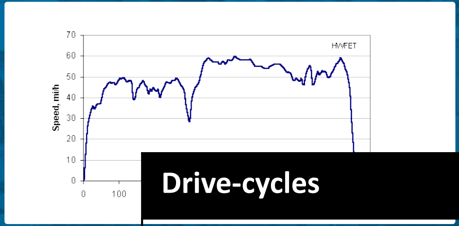


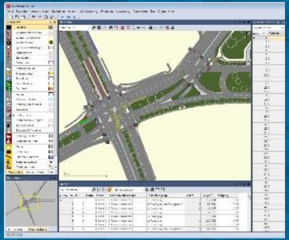
Optimal Control

AUTONOMIE

Fuel savings compared to baseline control

Modeling CAV Operations





Drive-cycles

- Direct changes to the drive cycles can model CAVs
- Modeling of interactions, control of speed, etc. impossible

Traffic-flow microsimulation

- Can model interactions between vehicles and infrastructure (to some extent)
- Expensive to build (and run)
- Can include powertrain models/control only in compiled form

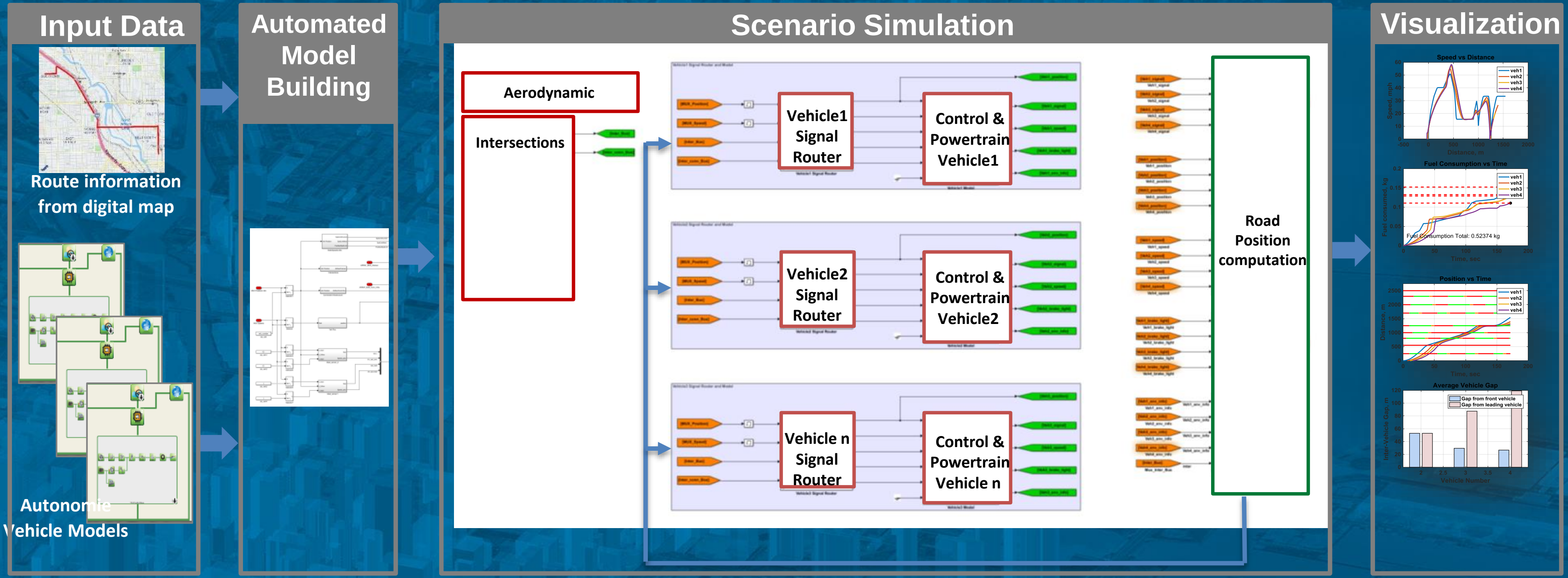
Powertrain/Energy Accuracy

Traffic Accuracy

RoadRunner

- Simulate both powertrain and driving interactions
- Easily run a broad range of route scenarios
- Integrate with Autonomie powertrain models
- Provide an environment for development and evaluation of **eco-driving** algorithms for CAVs

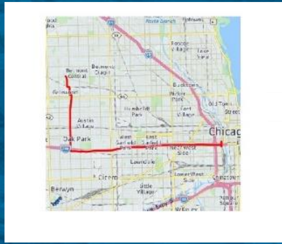
RoadRunner: Autonomie-Like Closed-Loop CAV Simulation Framework



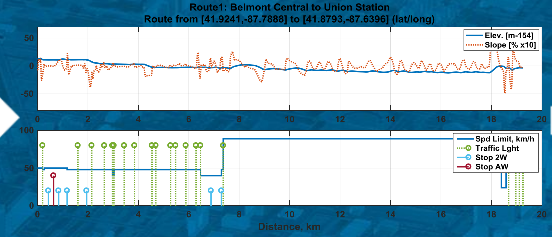
Powertrain Operations in Connected & Automated Driving

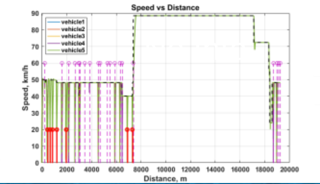
Preliminary Analysis Shows Both Positive & Negative Impacts on Component Operating Conditions due to Eco-Driving

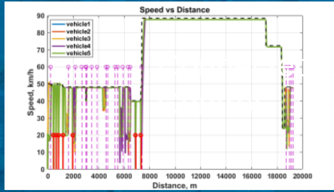
Select Route #1



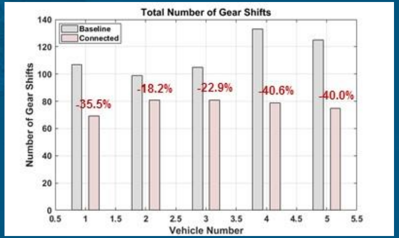
Extract Information



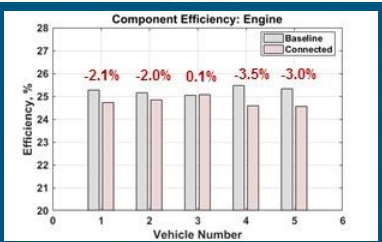




Decrease in Number of Shifting Events

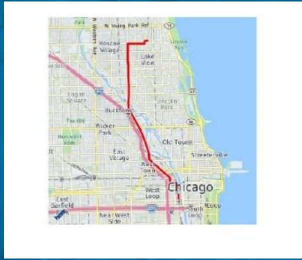


Decrease in Engine Cycle Efficiency

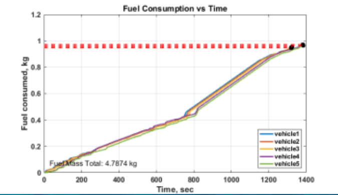


Energy Gains Highly Dependent on Scenarios

Select Route #2

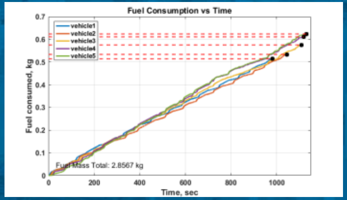


4.8% gains for Route #1



VS

9.2% gains for Route #1

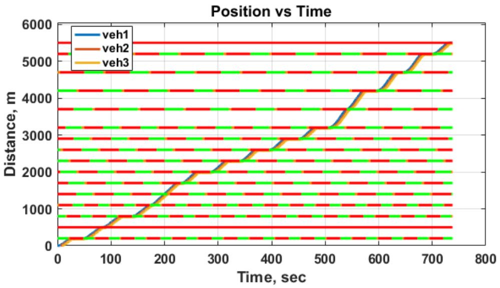


Scenarios also include # of vehicles, powertrain configurations, component technologies, control…

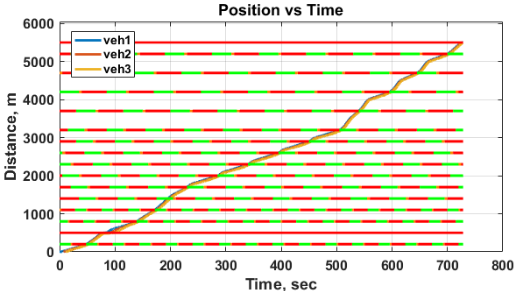
Energy Impact of V2V, V2I, I2V

EcoSignal

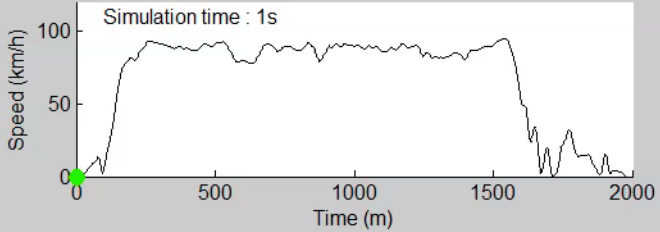
(1) Reference Vehicle

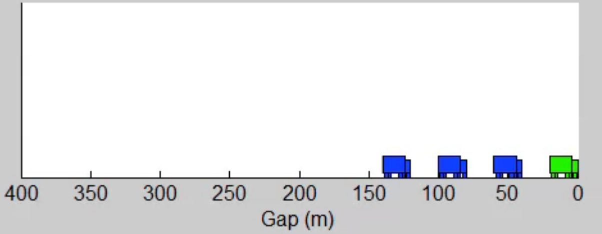


(2) Connected Vehicle



Platooning





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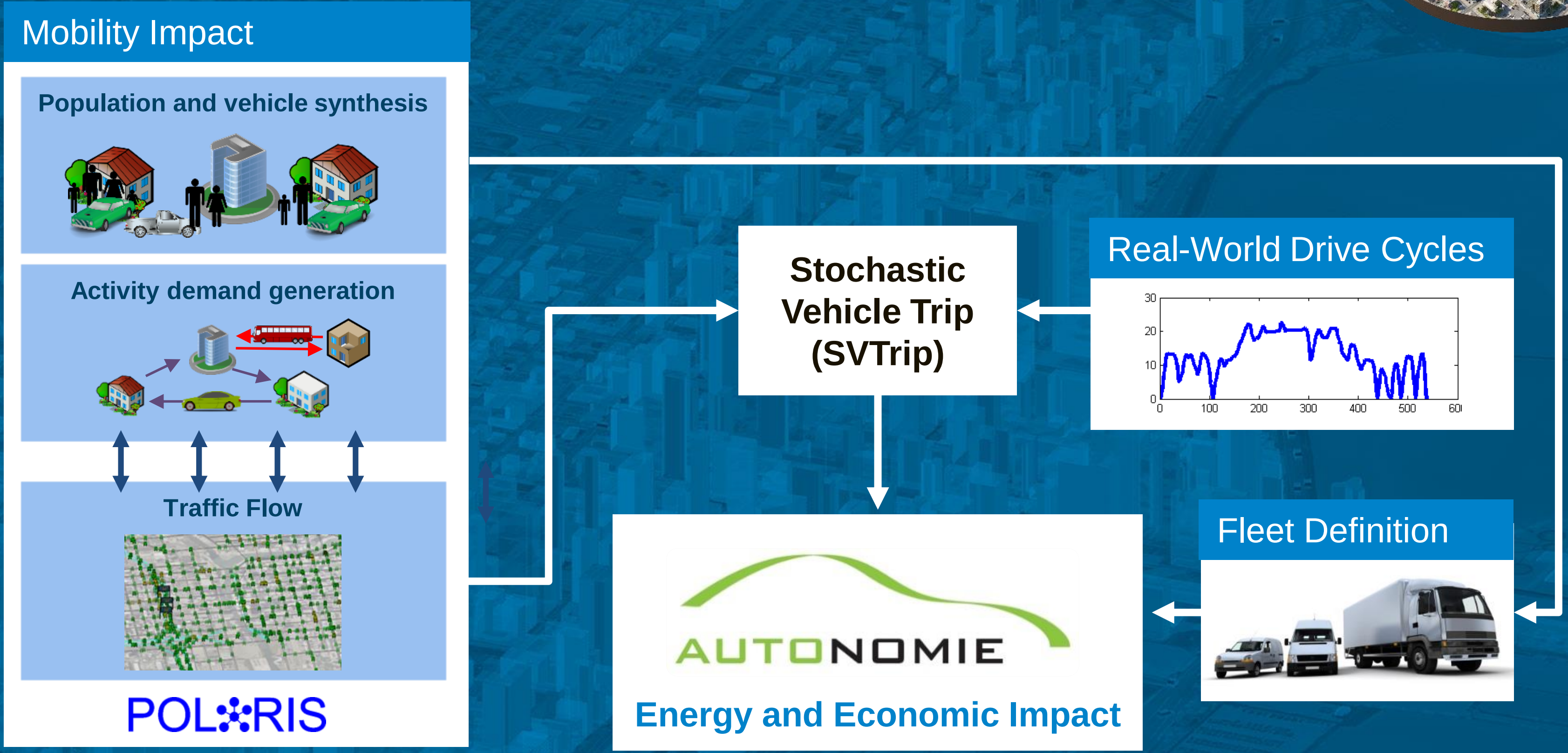
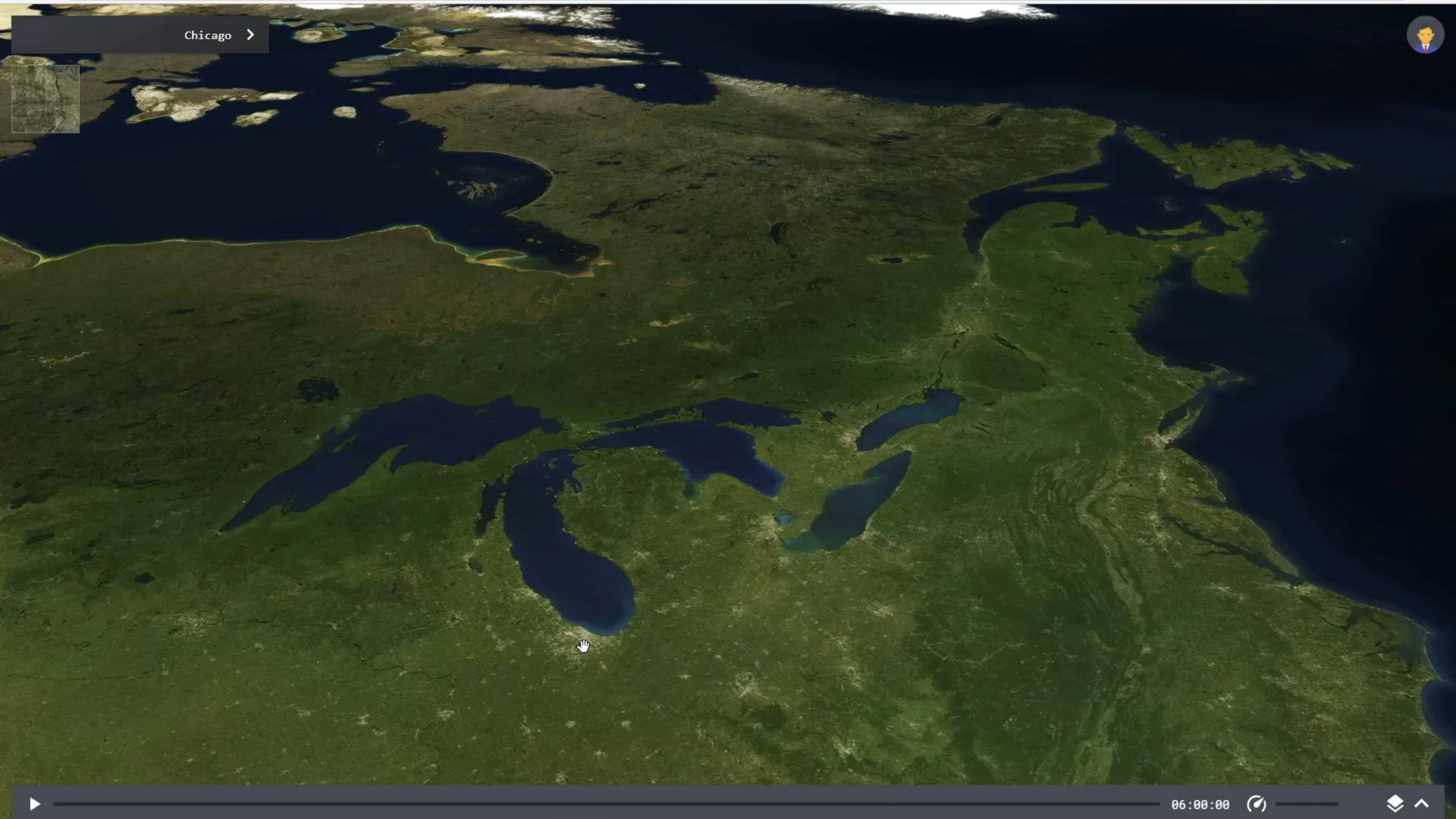
High-Performance, Agent-Based Simulation of Travelers and Transportation Systems

Mobility, Energy and Economic Impact at the Metropolitan Area




Chicago
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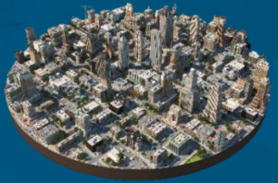
Examples of Future Mobility Scenarios Analyzed



Impact of coordinated platooning and CACC on energy use

Impact of multi-modal travel

CAV impacts on value of time and network performance

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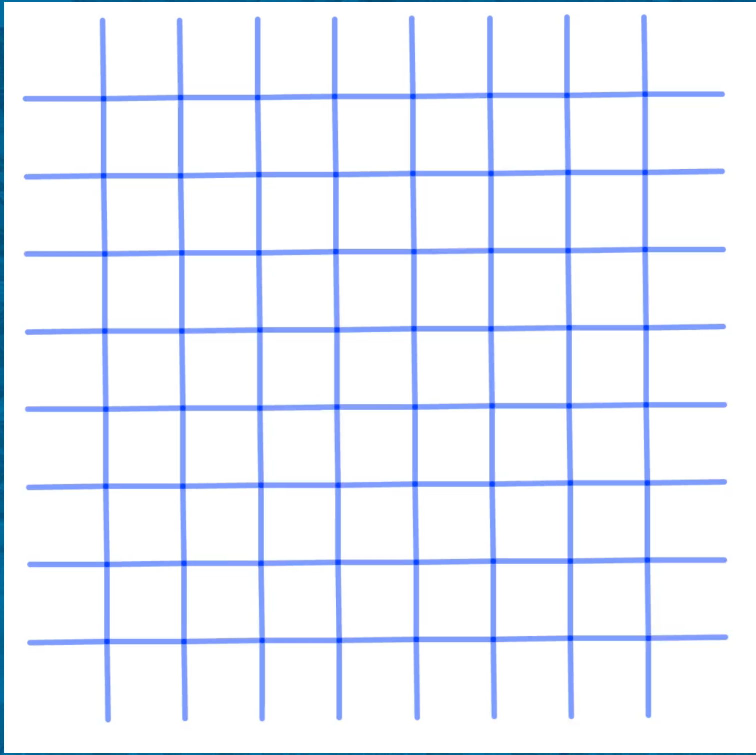
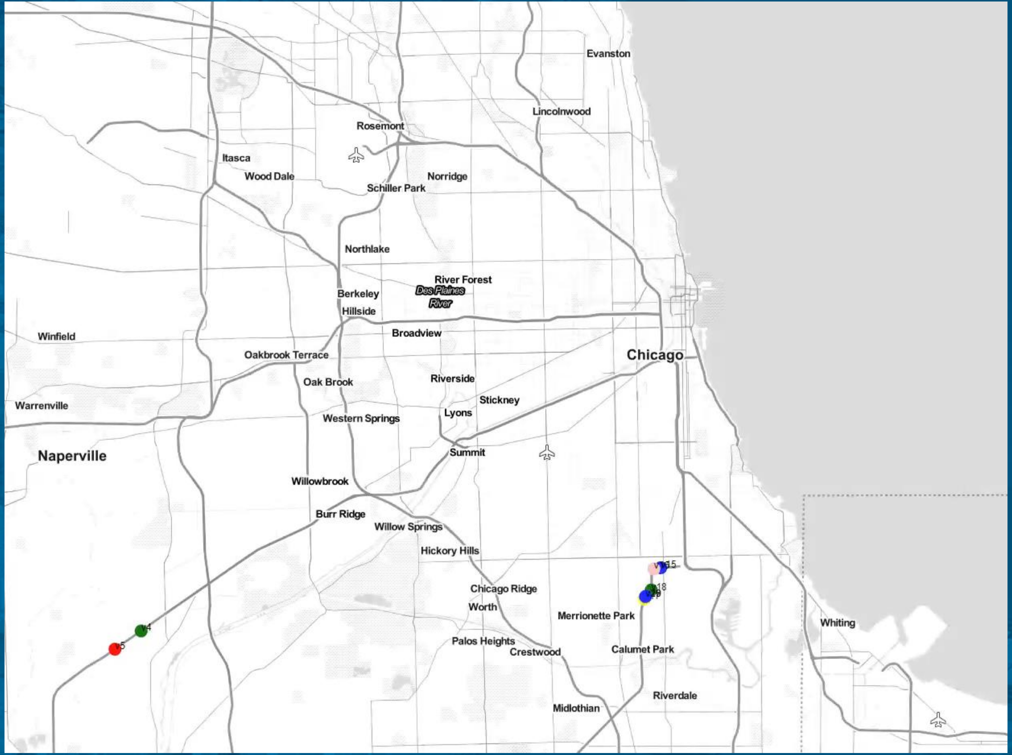
Platooning





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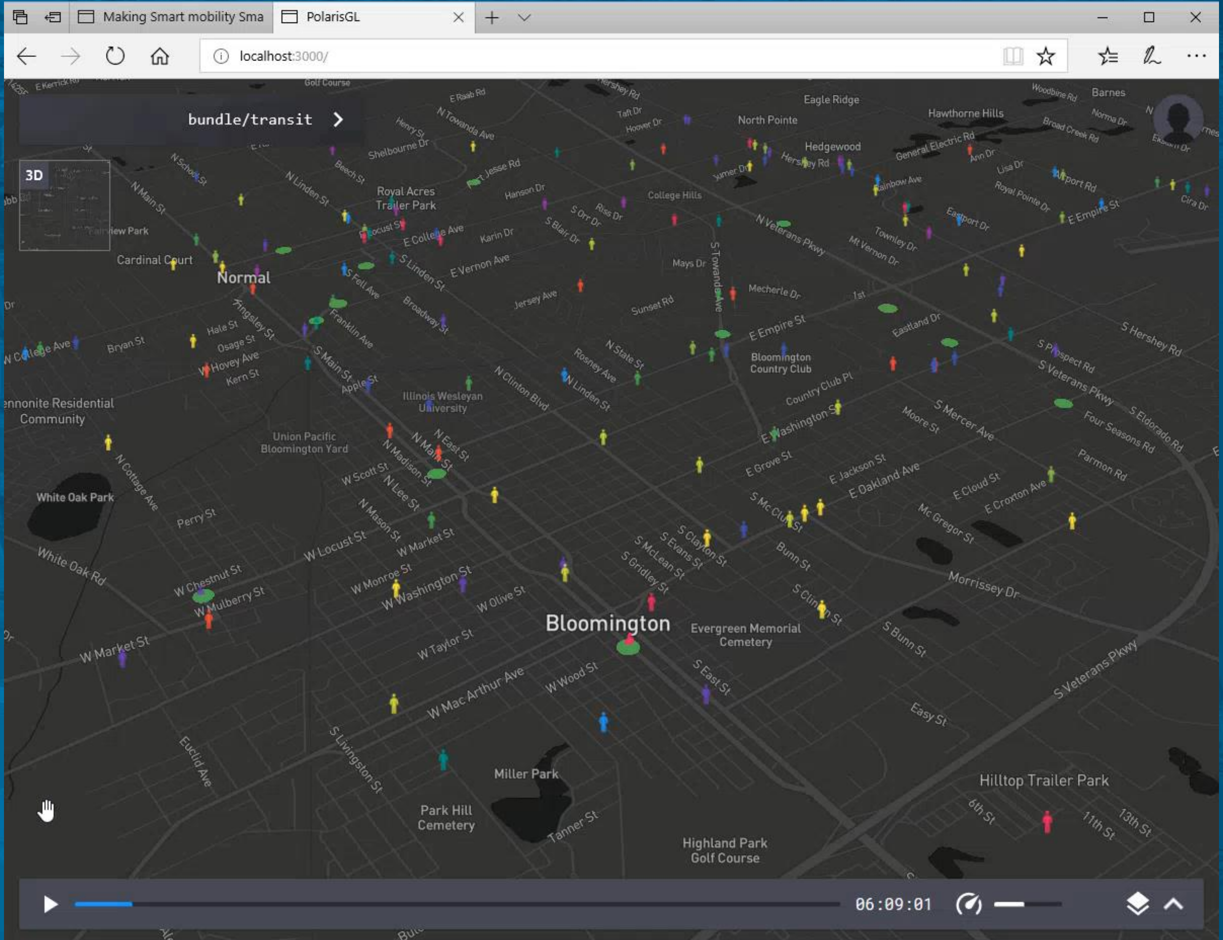
Multi-modal Travel



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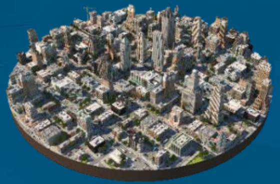
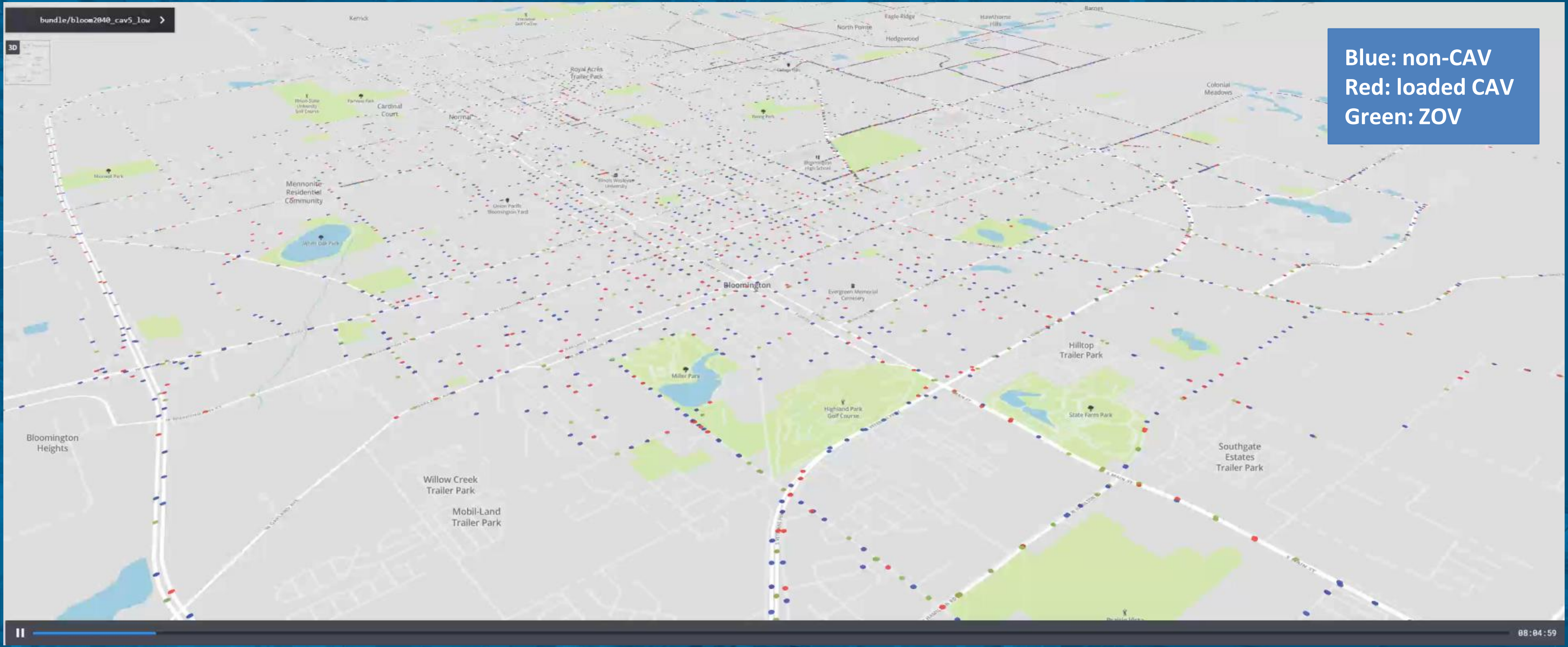
Level 5 CAV



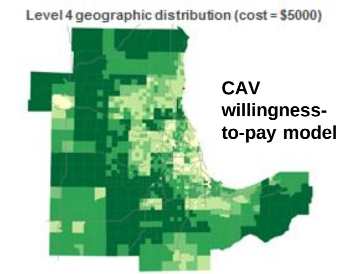


Blue: non-CAV
Red: loaded CAV
Green: ZOV

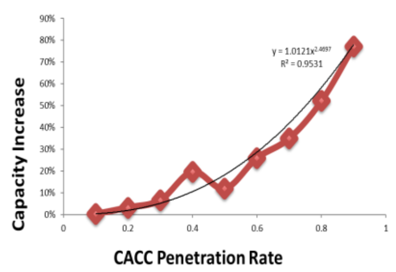
Energy Saved Might be Consumed by Additional Travel

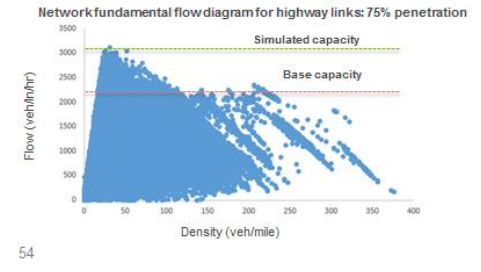
Travel Behavior Changes

VOTT changes under CAV in literature	VOTT in CAV or of a non-driving passenger in a car
Litman, 2009	35% to 70% of the wage rate
Schrank et al., 2012	$16 per hour
Bierstedt et al., 2014	25% to 50% of the wage rate
Gucwa, 2014	50% of the VOTT of the driver to VOTT in high-speed rail

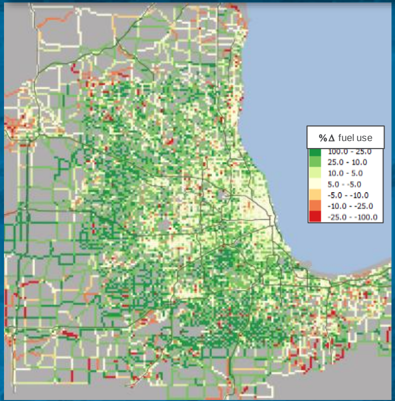


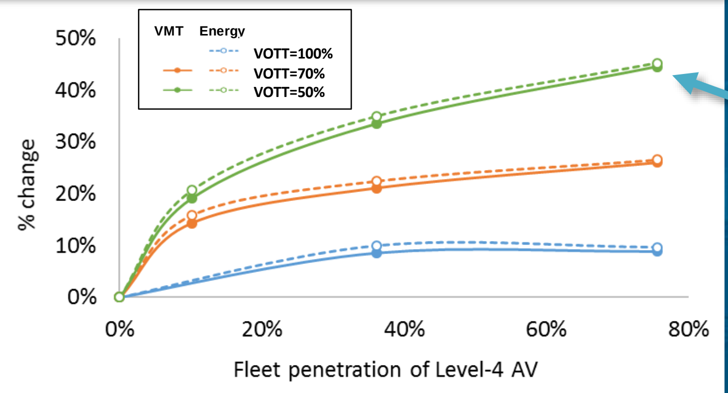
Traffic Flow Changes





Scenario results





~45% increase in fuel use in high penetration, low VOT scenario

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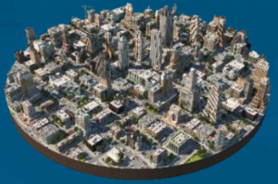
VERIFI

High Efficiency & High Throughput Enabled by HPC



Clusters

Super-Computer

First Exascale Machine in 2021 @ ANL

COST BENEFIT ANALYSIS: 12,000 cases, 64 cores/case

	Mira	Cluster
cases per ensemble	12000	16
cores per ensemble	768000	1024
time to science	4 days	6 months
total core-hr cost	$270K	$230K

Using Machine Learning to Estimate Vehicle Energy Consumption under Various Trip Scenarios

Estimate energy consumption on both standard and real world driving cycles using ML

US Standard Cycles

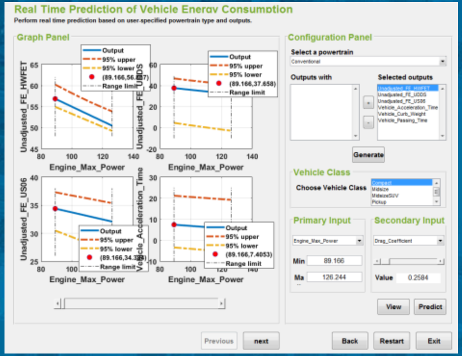
Autonomie Simulation Results (>1.5M combinations across 10 vehicle classes)

Real World Cycles

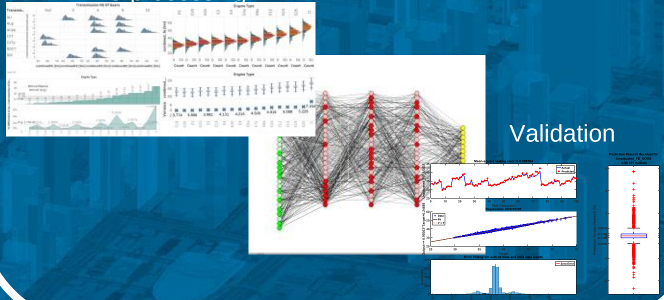
Autonomie Simulation Results (from POLARIS & RWDC)

UofM MTC FOA On-Road data

Machine Learning Tool / Workflow

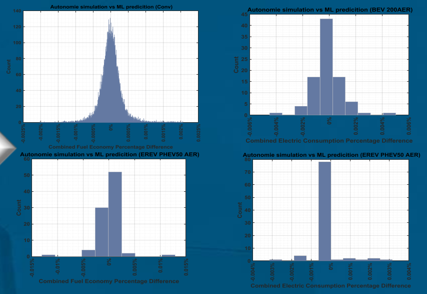


Pre-processing

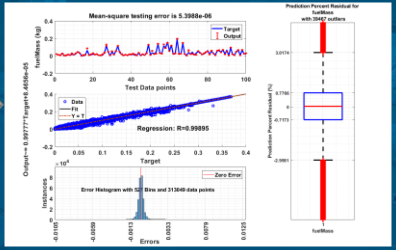


Validation

Excellent Prediction



Work in Progress, promising first results



AMBER Seamlessly Integrate New Workflows

Smart Mobility Example